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(54) Title: POWER LINE COUPLER MODEM DEVICE FOR COMMUNICATION OVER ELECTRICAL LINES

(57) Abstract

The present invention discloses an improved electrical communication apparatus which communicates high speed data/information over existing AC wiring (12), provides a phase linear environment for electrical transmission and reception of information on electrical wiring (12) and provides a means for simultaneous transmission and reception of multiple data/information streams (14, 22) via the use of dielectric core couplers (18). This invention provides a means for linking 2 or more microprocessor based or electronic devices via conventional electric lines such as power lines, building wiring, twisted pair, coaxial cable or other wiring.

POWER LINE COUPLER MODEM DEVICE FOR
COMMUNICATION OVER ELECTRICAL LINES

Field of the Invention

The present invention relates to communication apparatus
used to send and receive high speed data over electrical lines.
More specifically, it provides a means for high speed data to be
sent and received over conventional electrical wiring or other
electrical lines already existing in a building or over
preexisting power lines between buildings and structures.

Description of the Prior Art

Presently, there are a number of devices that allow
different types of information to be sent over electrical lines.
For example, there are intercom, stereo, switch control, and line
carrier modem systems which readily plug into an electrical
outlet and allow transfer of information over conventional wiring
to any other outlet in the same building.

The term conventional wiring includes wiring found in
buildings, homes or other structures. Conventional wiring can be
AC power lines, electrical wiring, coaxial, twisted pair,
telephone, antenna, multibase or any other wiring that can carry
electricity.

Intercom systems transfer a frequency modulated voice signal
over an electrical AC line which is received at another point or
socket on the electrical line and is demodulated back into its
voice components. Switch control systems consist of a main
switch control station plugged into an electrical outlet as well

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as multiple receiving stations plugged into other electrical
outlets. Each of the receiving stations may have a lamp or other
appliance plugged into it. The main switch control station
allows the user to press a selected button which switches a
selected appliance on or off at a receiving station. The
information sent from the switch control station to the receiving
station is generally a frequency modulated on top of the AC
voltage already present in the conventional electrical wiring.
The frequency is received by the individual receiving stations.
Each receiving station listens for a particular frequency which
indicates whether to switch to the off or on position. Here only
the simplest of information is sent over the conventional wiring.

There are also line carrier modems. A line carrier modem,
such as one described in, Keith Nichols, "Build a Pair of Line-
Carrier Modems," Radio Electronics, 87-91, (July 1988), is
connected to a computer or personal computer and then plugged
into an electrical outlet. Somewhere else on the same electrical
line another computer is connected to one of the line carrier
modems and also plugged into an electrical outlet. Data can be
communicated from one computer to another via the line carrier
modems. Generally, such modems, take a single data stream from
the computer, modulate the data stream, then place it on top of
the AC voltage present in the conventional wall wiring. This
signal is then received by a second line carrier modem and
demodulated back into the original data stream so that the second
computer can receive the data from the first computer.

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Existing line carrier modems are limited to a baud rate of 19.2 kbaud or less. This limitation is mainly due to the use of magnetic or iron core transformers in their design. These iron core transformers are used to couple the modulated data stream from the line carrier modem onto and off of the conventional wiring. These magnetic core couplers are not impedance matched to the electrical line characteristic impedance, and thus distort the modulated signal. This distortion limits the transmission and reception baud rate to 19.2 kbaud. Spread spectrum techniques are used in existing line carrier modems due to the problem encountered with standing waves. A standing wave occurs due to the mismatched impedance of the magnetic core couplers and the electrical line which causes a reactive coupling at carrier frequency. The standing wave will cause null points on the conventional wiring; the effect of which will cancel the transmission at the null point. Existing transmission or receiving line carrier modems, with their iron core or magnetic core transformers, are inept at filtering out a majority of the 60Hz harmonics from a 60Hz 120 volt electrical line. Iron core or magnetic core transformers/couplers are also phase non-linear, thus modulated signals sent along conventional wiring are of a different phase when received then as when transmitted. This unpredictable phase shift, associated with the coupling of the modulated signal to the electrical line, severely limits the use of encoding digital data with phase shift keying techniques.

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At present, local area networks (LANs) and networking
systems, such as Ethernet, are the industry choice for connecting
multiple computer stations together. These networks generally
consist of multiple computer stations, a network server, and a

5   hard wired bus and/or electrical lines connecting every computer
system. Each computer or station on the system has an address
known by all the other computers or stations. For a first
station to communicate with a second station it merely sends the
address of the second station on the bus followed by pertinent

0   data information. The information is received by a second
station with the proper address. The second station may transmit
data back to the first station using the same process.

LAN or Ethernet systems are expensive to install. One
reason for the expense is the purchasing and installation costs

5   of wiring an office complex. Wiring often must be installed
underneath the floors or through the walls in order to meet
building codes. At a later date, the installation of more wiring
may be required to expand the system.

Local area networks and Ethernets transmit data over their

0   communication lines at an extremely high rate of speed. This
rate of speed can be up to and greater than 10 Mbaud on coaxial
line and about 1 Mbaud over multiple twisted pair. At present,
there is no available system that allows LAN or Ethernet
expansion without hard wiring additional cabling throughout an

5   office building. As mentioned earlier, existing line carrier
modems can only transmit and receive data at about 19.2 kbaud.

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They are not useful for expanding Ethernet or LAN systems because linking a pre-existing LAN System to presently existing line carrier modems for expansion purposes will slow the entire network down or make the system inoperable.

SUMMARY OF THE INVENTION

The invention includes communication apparatus which transmits and receives multiple modulated signals over an electrical line having a first station capable of receiving high speed data and converting the high speed data into multiple modulated signals for sending simultaneously over the electrical line to said second station. The second station is capable of simultaneously demodulating the multiple modulated signals and converting the signals back into high speed data; and each of the stations incorporates dielectric core couplers for coupling the multiple modulated signals between the electrical line and each station.

In light of all the foregoing, it is a primary object of the present invention to transmit and receive data at baud rates greatly exceeding 19.2 kbaud over preexisting conventional wiring.

It is a further object of the present invention to transmit and receive data over conventional wiring in a phase linear fashion such that phase shift keying techniques can be used in sending and receiving digital data.

It is another object of the present invention to resistively match a Power Line Coupler Modem to the electrical wiring characteristic impedance at the transmission frequency in order to eliminate standing waves. The elimination of standing waves will allow the Power Line Coupler Modem to transmit and receive without using spread spectrum modulation/demodulation techniques.

It is another object of the present invention to send and receive multiple modulated signals at the same time over conventional wiring.

It is yet another object of the present invention to provide an inexpensive means for installing and expanding LAN or networking systems such as Ethernet or Token Ring, etc.

It is an additional object of the present invention to allow multiple computers or stations to communicate via pre-existing electrical lines found within a building.

It is a further object of the present invention to allow computer systems to communicate via pre-existing power lines between buildings such that work stations or computer systems in one building can communicate with multiple work stations and/or computer systems in other buildings.

It is another object of the present invention to transmit and receive clear audio or video analog signals via conventional wiring in a phase linear manner.

DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of basic Power Line Carrier

Modem (PLCM) of the present invention.

Figure 2 is a block diagram of the PLCM organized to handle

serial inputs and outputs.

Figure 3 is a block diagram of the PLCM incorporating

quadrature phase shift keying in the modulation and demodulation

stage.

Figure 4 is a block diagram of the PLCM incorporating

quadrature phase shift keying and capable of handling high speed

serial inputs and outputs.

Figure 5 is a block diagram of the PLCM configured to

operate within a Local Area Network (LAN) system.

Figure 6 is a block diagram of the PLCM configured to

operate within an Ethernet.

Figure 7 depicts numerous computers, printers and various

devices interconnected via the PLCM.

Figure 8 depicts the coupling transformer of a power line

coupler of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

The present invention, a Power Line Coupler Modem (PLCM),

provides a means for high speed data communication over

conventional wiring. The invention modulates multiple signals at

different preselected modulation frequencies, then combines and

sends the multiple modulated signals over conventional wiring.

The multiple modulated signals are then received, separated and

individually demodulated. Power Line Couplers, described in my

pending patent application Serial No. 822,326, are used in the

present invention to place and retrieve the multiple modulated

signals onto and off of the conventional wiring. These couplers

are phase linear at and close to their preselected frequencies

and are capable of removing a majority of the AC harmonics

associated with power line frequencies (60Hz) found on

conventional wiring. Furthermore, operation of the PLCM can

reach speeds in excess of 1 MBaud (with four to ten couplers) for

3 KM distances. It is emphasized that the transmission is in a

parallel form rather than a serial form.

Figure 1 depicts a basic Power Line Coupler Modem (PLCM) 10

which consists of at least two Power Line Couplers $(C_1 - C_n)$ 18

plus an equal number of modulators $(M_1 - M_n)$ 16 and demodulators

$(D_1 - D_n)$ 20. Data, usually in the form of a digital bit stream,

comes from a device capable of sending parallel digital data (not

shown), such as a personal computer or microprocessor based

device. It should be noted that the data could be analog

information such as voice, video, stereo, or other analog signals.

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Data enters the PLCM 10 via the parallel inputs 14. The
data is modulated to a preselected modulation frequency by its
associated modulator (M_1 - M_n) 16. After each data stream is
modulated at the modulators it is passed to its associated

5   coupler (C_1 - C_n) or Power Line Carrier (PLC) 18. Each coupler
18 is phase linear and resistively matched at or around the
modulation (carrier) frequency to the characteristic impedance of
the AC power line 12 to which it is connected. Each coupler
(C_1 - C_n) 18 is connected to one another resulting in an addition

)   of all the modulated data streams as they are connected to the
conventional wiring or AC power line 12.

A second PLCM, shown in Figure 1, is identical to the first
PLCM 10. The addition of all the modulated data streams enters
the second PLCM 10 from the AC power line 12. The couplers of
Figure 8 (C_1 - C_n) 18 are impedance matched to the AC power line
12 and phase linear at the preselected filter frequencies. Each
coupler filters the incoming signal and extracts a single
preselected modulated data stream. The modulated data stream is
sent from the couplers (C_1 - C_n) 18 to an associated demodulator
(D_1 - D_n) 16. Each demodulator 16 removes the modulating carrier
signal from the data leaving the data which was sent by the first
PLCM. This data is placed onto its associated parallel output
lines. The output lines carry the data to an electronic device
capable of receiving parallel digital data such as a computer,
printer, or other electronic device.

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This entire communication process can be repeated in the opposite direction. That is, the second PLCM can send data to the first PLCM via the AC power line 12. The generic data rate at which the parallel input 14 and output 22 lines are capable of operating at is in the range of 50 to 100 KSymbols/sec for each line. The PLCM can be configured to handle any size parallel bus and the signals on the bus can be anything from DC voltage levels to binary signals to multiple analog signals.

The maximum communication distance is calculated from the raw speed of each digital bit stream. Dividing the speed of an electron, 300,000 km/sec, by the speed of the bit stream, 100 KSymbols/sec, we get 3 km/bit. Normally only a fraction of the 300,000 km/sec can be assumed for electron speed, thus the maximum communication distance will be closer to 2 km.

Figure 2 depicts the basic PLCM 10 wherein the parallel inputs 14 are connected to a demultiplexer 26 and the parallel outputs are connected to a multiplexer 28. In this configuration the PLCM 10 can receive serial or parallel (herein "data stream) data stream on the input line 24 from a device capable of sending a data stream (not shown). The demultiplexer 26 receives the data stream and converts it to parallel data for the parallel input lines. The PLCM then operates as described above. In short, each signal on the parallel input line is modulated, then coupled to the AC power line. The signal is then received by a second PLCM wherein the modulated signals are coupled to the

PLCM, separated, filtered, demodulated and sent out on the parallel output lines 22.

The parallel output lines 22 are connected to a multiplexer which converts the parallel data back to its original data stream. This data stream can be received by an electronic device designed to receive serial or parallel data.

For example, referring to Figure 7, PC1, a personal computer, may have a data stream port through which it sends and receives data. PC1 may send data to PC2 through the AC power line by first sending the data stream to a first PLCM which connects the data in a modulated format onto the AC power line. A second PLCM then can receive the modulated data, change it back into its original data stream form and connect it PC2 which, in turn, receives the data. Each transmission is addressable to preselect the destination.

Since the basic PLCM configuration is capable of handling a symbol rate of 80 KSymbols/sec per each input or output parallel line, the addition of another parallel line acts as a data speed multiplier increasing the baud rate and overall throughput of the PLCM. For example, if two modulators and demodulators are used in each PLCM the overall throughput of the PLCM is 80 KSymbols/sec X 2 = 160 KSymbols/sec. If eight modulators and demodulators are used in the PLCM the overall throughput of the PLCM is 80 KSymbols/sec parallel line X 4 parallel lines = 320 Kbaud.

Quadrature phase shift keying modulation techniques are illustrated in Figure 3. As explained herein, quadrature phase shifting can be used successfully in the novel PLCM to double the baud rate of each input or output parallel line in the PLCM.

Figure 3 depicts a phase shifting PLCM 10a with parallel input lines 14 which carry digital data into the quadrature phase shift keying (QPSK) modulator 34. The QPSK modulator assigns a 90, 180, 270 or 360 degree phase shift for each two bits of data and shifts the modulation frequency accordingly. For example, data bits "00" are assigned a 90 degree phase shift, "01" are assigned 180, "10" are assigned 270 degrees and "11" assigned a 360 degree shift. This technique essentially packs the data in a 2:1 ratio. Thus, the speed of each parallel input line is increased by a factor of two over the general modulation technique described in the basic PLCM.

The shifted modulation signal is coupled to the AC power line 12 by the PLCs 18. As with the basic PLCM all parallel shifted modulation signals are added together into a conglomerate modulation signal and sent over the AC power line to a second PLCM 10a. The second PLCM 10a (not shown) located at another point on the AC power line 12 receives the conglomerate modulation signal and separates and filters each distinct signal at the couplers 18.

Since the PLCs 18 are phase linear due to the use of air-core transformers and impedance matched to the AC power line at the modulation frequency, the encoded phase shifts are

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undisturbed when passing through them. Each shifted modulation

signal proceeds to the phase lock loop (PLL) circuit 36. The PLL

36 assures the specific predetermined frequency and bandwidth are

locked onto and do not drift prior to insertion into the QPSK

5   demodulator 34. A possible bandwidth for the PLL is 50 KHz.

Other frequency locking circuits can be used here as well.

        At the QPSK demodulator the phase shifts in the modulated

signals are demodulated (decoded) back into their original

digital form. A 90 degree phase shift is demodulated into a "00"

)   a 180 degree phase shift to a "01", and so forth. The data

stream is then sent out on the associated parallel output data

line.

        Figure 4, similar to Figure 2, depicts how multiplexer and

demultiplexer circuits can increase the baud rate of the phase

;   shifting PLCM 10a to that of a high speed data stream input or

output line. The multiplexer receives input data on the data

stream input line then converts the data to multiplexed parallel

data and connects the data to the parallel input lines. The data

rate on each input parallel line is equal to the speed of the

ı   input data stream divided by the total number of parallel input

lines. The more parallel input data lines the greater the speed

of the data stream input lines that can be catered to by the

PLCM. Using QPSK modulation each parallel input and output

parallel data line operates at baud rates of about 160 kbaud.

Therefore, if eight input and output data lines are used the

overall throughput of the PLCM using quadrature phase shift

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keying is 160 Kbaud multiplied by four, totaling 640 Kbaud. The
use of more than eight input and output data lines can increase
the baud rate dramatically.

If an eight state phase shift modulator (octaphase shift key
modulator) (OPSKM) is used instead of a quadrature phase shift
modulator (four state modulator) then every three bits of data
are assigned to each forty-five degree shift in phase. For
example, "000" is assigned a 45 degree phase shift, "001" is
assigned a 90 degree phase shift, "010" is assigned 135 degrees,
"011" gets 180 degrees, "100 gets 225, "101" gets 270, "110" gets
315, and "111" gets a 360 degree phase shift assigned to it.
This technique packs the data in a 3:1 ratio. Thus, the speed of
each parallel input line is increased by a factor of 3 over the
general input line. Using OPSK modulation and eight parallel
input lines, each input line through put will be approximately 80
KSymbols/sec x 4 equaling 320 KSymbols/sec. Multiplying by eight
lines the total throughput of a PLCM using OPSK modulation is
about 2.5 MSymbols/sec.

The demultiplexer circuitry 26 operates the same way as
described for figure 2. The parallel output lines 22, in figure
4, carry the digital data from the QPSK modulators 34 to the
multiplexer where it is multiplexed from parallel to data stream
data and sent out on the data screen output line 30.

For example, a Digital Signal Processing (DSP) chip can be
used, using the ATT DSP 32C in which the digital bandpass filter,
the PLL and the OPSK MOD/DEMOD can be programmed. The Carrier

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Sense Multiple Access/Collision Detection will be handled in the
PLC modem. Logical separation of LAN traffic (addressability)
may be used as well as the Forward Error Correction (FEC) and
Data Compression, all of which are controlled by the CPU.

5   Obviously, the best carrier frequencies which can be chosen
between the main harmonics of the 60 Hz, are every 30 KHz in the
spectrum. In that case, the 1:1 received inband noise
(threshold) is only around 5-15 mV peak to peak. Thus, ten
channels can be used at the following carrier frequencies:

0   F1=165 KHz, F2=195 KHz, F3=225 KHz, F4=255 KHz, F5=285 KHz,
F6=315 KHz, F7=345 KHz, F8=375 KHz, F9=405 KHz, F10=435 KHz using
about 20-24 KHz bandwidth for each channel and OPSK. Similarly,
about 33.33 KSymbols/sec per channels and 1Mbaud final speed can
be reached. The usage of more channels will bring up the price

5   of the modem and since the strong 60Hz harmonics are only every
60 KHz in the spectrum, therefore only four channels are
recommended at the following carrier frequencies, while the noise
threshold remains about the same as above: F1=210KHz, F2=270 KHz,
F3=330 KHz, F4=390 KHz, using about 50-54KHz bandwidth for each

)   channels and OPSK. Similarly, about 83.33 KSymbols/sec per
channels and 1 Mbaud final speed can be reached. It is also
possible to add a fifth channel at 150KHz. In Europe, the Power
Line carrier frequency rules are different. They do not allow
higher than 100KHz frequency transmission, therefore four

5   channels are recommended at the following carrier frequencies:
F1=56KHz, F2=69KHz, F3=82KHz, F4=95KHz using about 9KHz bandwidth

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for each channel and OPSK. The maximum final speed can be about
200Kbaud. Since they have 50Hz power, the strong harmonics
appear at every 25KHz in the spectrum, and the threshold is
around 15-40mV peak to peak.

Figure 5 and Figure 6 depict examples of how the PLCM and
modulator/demodulator circuits can be used in coexistence with
network controllers used in a Local Area Network (LAN) system,
(Figure 5), or other networking system, (Figure 6). This is an
inexpensive technique for creating or expanding a LAN or Ethernet
System because no additional wiring must be added to interconnect
the system. Other network controllers such as Starlan, Token
Ring, etc. can also be used. Also, the use of various types of
network software, such as Novell, can be implemented.

Power Line Couplers (PLC's), as described in my co-pending
application serial number 822,326 filed Jan. 17, 1992, are part
of the present invention's embodiment because of their linear
phase shifting qualities. PLC's allow signal information to be
placed on conventional electrical wiring and retrieved, noise
free, at another position. PLC's allow communication over
existing electrical power AC wiring found in buildings. PLC's
also allow for communication over long distance through power
lines outside buildings. Such a configuration on outside wiring
will allow efficient data communication from building to building
without the installation of new cabling. With a PLCM, which
incorporates a PLC, existing electrical wiring in any form can

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become a means for transmitting and receiving communications at
rates of speed that can exceed 1 Mbaud.

Figure 7 depicts a possible configuration for data
communication between multiple microprocessor based and
electrical/electronic equipment. Any personal computer (PC),
printer, or other device can be connected to a PLCM 10, 10a. The
PLCM, plugged into a standard wall socket, will allow the device
to transmit and/or receive communication information over the
electrical wiring of the building 12.

Note that if multiple phases are present (phase A, B, & C)
and devices which must communicate via a PLCM are connected to
separate phases, then a simple circuit 70 can be used to link the
phases together.

While particular embodiments of the present invention are
disclosed herein, it is not intended to limit the invention to
such disclosure, and changes and modifications may be
incorporated and embodied within the scope of the following
claims.

What is claimed is:

1.　　A communication apparatus which transmits and receives multiple modulated signals over an electrical line which comprises:

a first station and a second station;

said first station capable of receiving high speed data and converting the high speed data into multiple modulated signals for sending simultaneously over the electrical line to said second station, said second station being capable of simultaneously demodulating the multiple modulated signals and converting the signals back into high speed data; and

each said station incorporating dielectric core couplers for coupling the multiple modulated signals between the electrical line and each station.

2.　　A communication apparatus in accordance with claim 1 wherein the dielectric-core couplers couple the multiple modulated signals between the electrical line and each station in a phase linear manner.

3.　　A communication apparatus in accordance with claim 1 wherein the electrical line is any conventional wiring.

4.　　A communication apparatus in accordance with claim 1 wherein the multiple modulated signal sent over the electrical line can be sent for a distance of 3km.

5.　　A communication apparatus in accordance with claim 1 wherein the multiple modulating signal is a combination of

multiplexed digital data which is modulated at different distinct preselected frequencies and then combined.

6.   A communication apparatus in accordance with claim 1 wherein the high speed data is serial data traveling at a rate of up to 100 KSymbols/sec.

7.   A communication apparatus in accordance with claim 1 wherein each station utilizes quadrature phase shift keying techniques when modulating and demodulating the multiple modulated signals.

8.   A communication apparatus in accordance with claim 6 wherein the high speed data is serial data traveling at a rate of at least 160 kbits/sec.

9.   A communication apparatus in accordance with claim 1 wherein each station utilizes octaphase shift keying techniques.

10.   A communication apparatus in accordance with claim 7 wherein the data error rate of the communication apparatus is less than 10^{-9}.

11.   A communication apparatus which transmits and receives composite modulated signals over an electrical line at high speeds comprising:

a first station and second station connected to each other by an electrical line;

each station including multiple input and output data lines, modulators, demodulators and air-core couplers;

multiple output data lines carry electrical information to modulators, one data line to each modulator;

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said modulators, each operating at a different preselected

modulation frequency, modulate output data received from a

corresponding output data line and pass such modulated data

signal to an air-core coupler;

each air-core coupler, which is phase-shift linear and

impedance matched with the electrical line at the preselected

modulation frequency, couples each modulated output data signal

to the electrical line by creating and output composite signal;

each air-core coupler also receives an input composite from

the electrical line and separates the input composite signal into

parallel input modulation signals, without effecting the phase of

the parallel input modulation signals, and passes said input

modulation signals to the demodulators;

each demodulator, one for each input modulator signal,

demodulates the input modulation signal and transmits it on an

input data line as input data.

12. A communication apparatus in accordance with Claim 11

wherein all input data lines are connected to a multiplexer which

multiplexes the electrical information on the input data lines

into an input data stream line and

all input data lines are connected to a demultiplexer

which demultiplexes the electrical information on the output data

stream line onto the output data lines.

13. A communication apparatus in accordance with Claim 12

wherein the input and output data stream lines operate

3   individually at approximately 80 KSymbols/sec multiplied by the

4   number of input or output data lines.

1   14. A communication apparatus in accordance with Claim 11

2   wherein the air-core couplers have a dielectric core.

1   15. A communication apparatus in accordance with Claim 11

2   wherein the electrical information on the input and output data

3   lines is analog information.

1   16. A communication apparatus in accordance with claim 12

2   wherein demodulators incorporate phase-lock-loop circuitry prior

3   to demodulation.

1   17. A communication apparatus in accordance with claim 16

2   wherein modulators and demodulators incorporate Quadrature Phase

3   Shift Keying Circuitry.

1   18. A communication apparatus in accordance with claim 16

2   wherein modulators and demodulators incorporate octaphase shift

3   keying circuitry.

         19. A communication apparatus in accordance with claim 11

     wherein each station includes a multiplexer, demultiplexer,

     serial input line and serial output line;

         each data stream output line carries output data to a

multiplexer;

         said multiplexer multiplexes the data stream output data

onto the multiple output data lines;

         each demultiplexer receives input data from the input data

lines and demultiplexes the data into data stream input data and

sends the input data on the data stream input line.

1   20. A communication apparatus in accordance with claim 17

2   wherein both the data stream input and data stream output line

3   travel at data speeds exceeding approximately 1 Mbaud.

1   21. A method of communication which allows multiple

2   electronic processors to communicate on an electrical line

3   comprising:

          providing a first encoder/decoder connected to a first

electronic processor and at least a second encoder/decoder unit

connected to a second electronic processor, both first and second

encoder/decoder units being connected to an electrical line and

utilizing air-core couplers;

          receiving a first data stream from the first electronic

processor;

          multiplexing the first data stream into multiple parallel

data streams;

          modulating each parallel data stream at a different distinct

preselected modulation frequency resulting in multiple modulated

data streams;

          combining the multiple modulated data streams into a

combination data stream;

          sending the combination data stream on the electrical line

in a phase linear manner;

          receiving the combination data stream at the second

encoder/decoder unit;

separating the combination data stream, in a phase linear

manner, into multiple modulated data streams each modulating at a

different distinct modulation frequency;

demodulating each modulated data stream and creating

parallel data streams;

demultiplexing the parallel data streams into a single

second data stream;

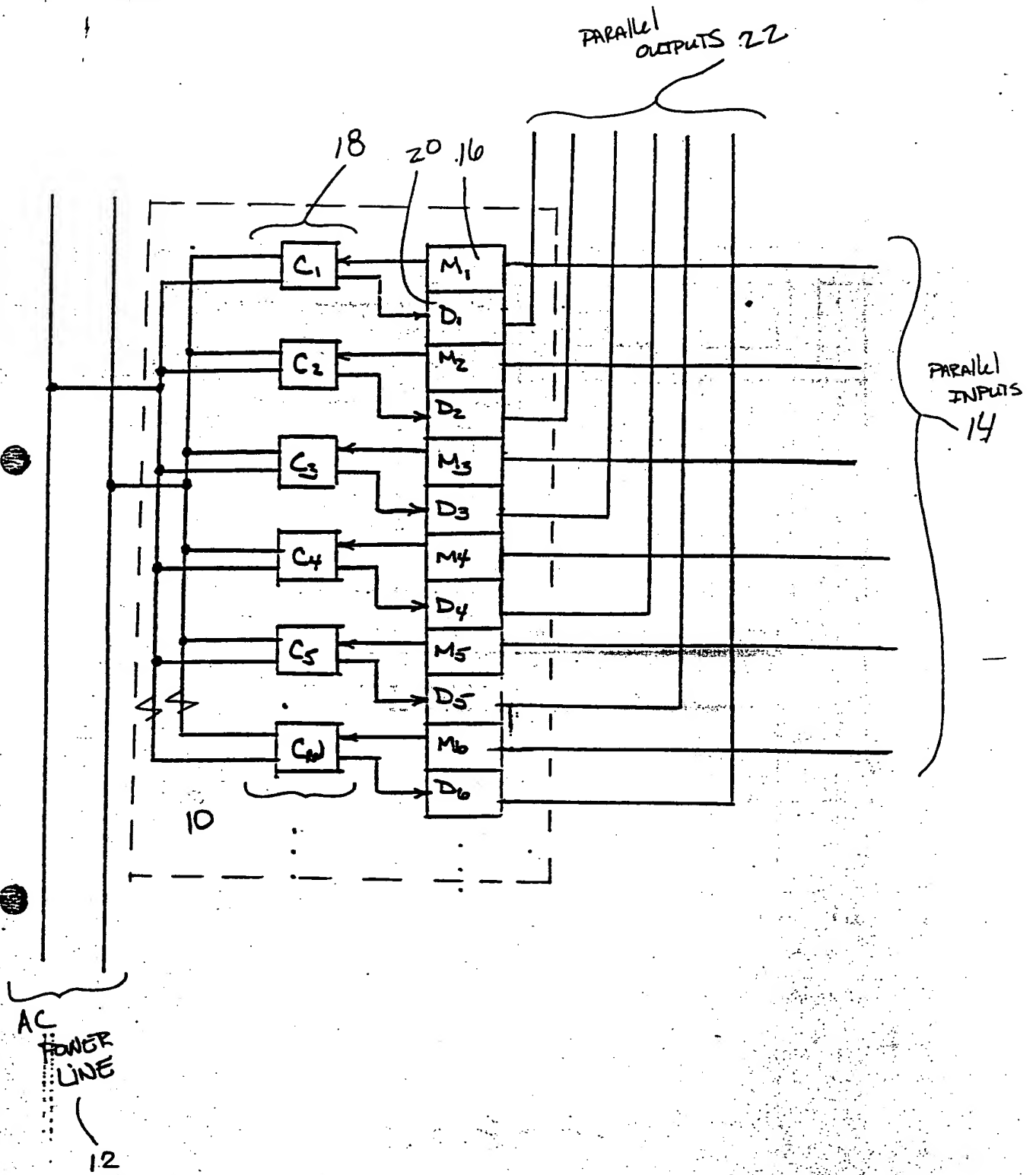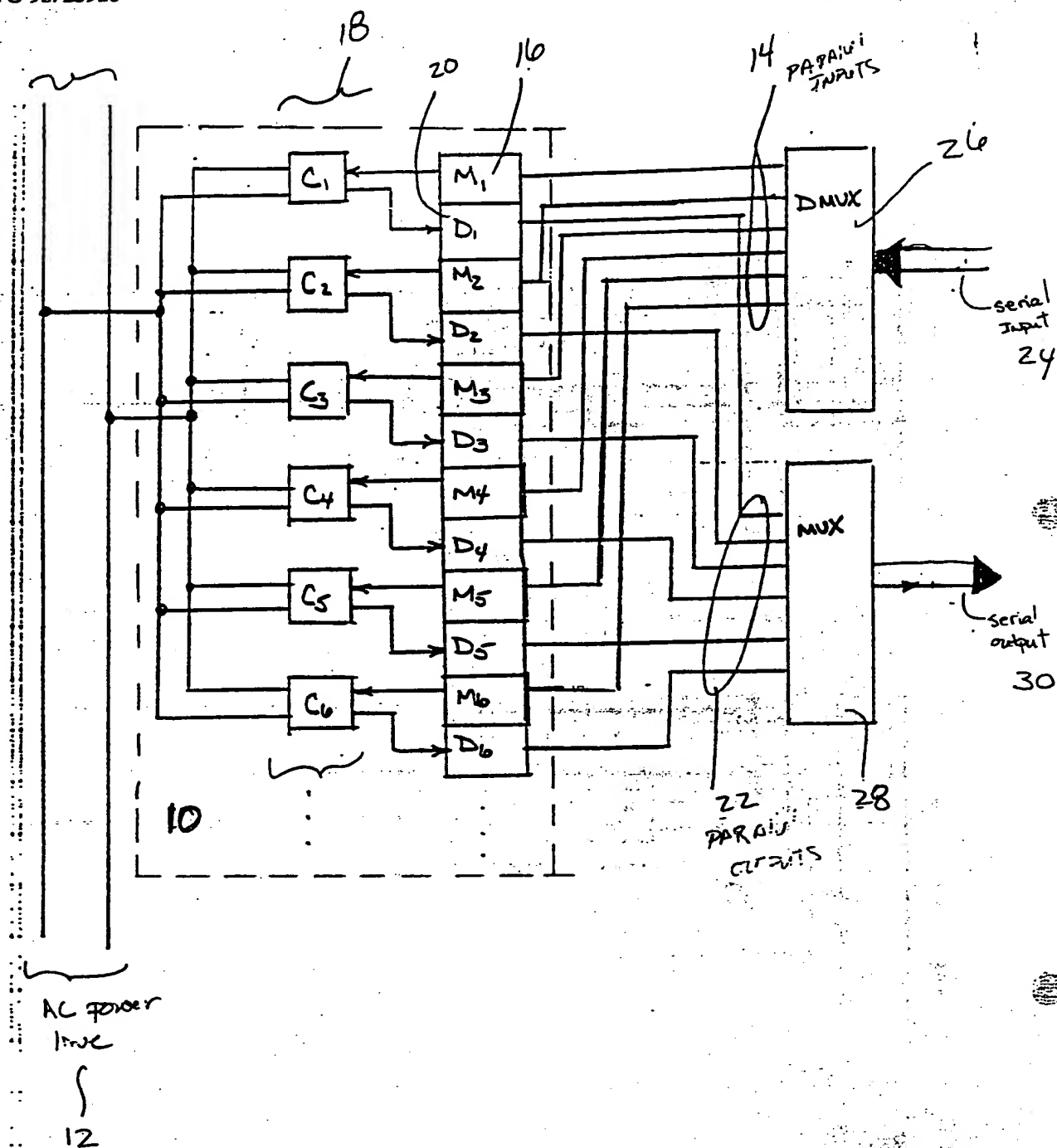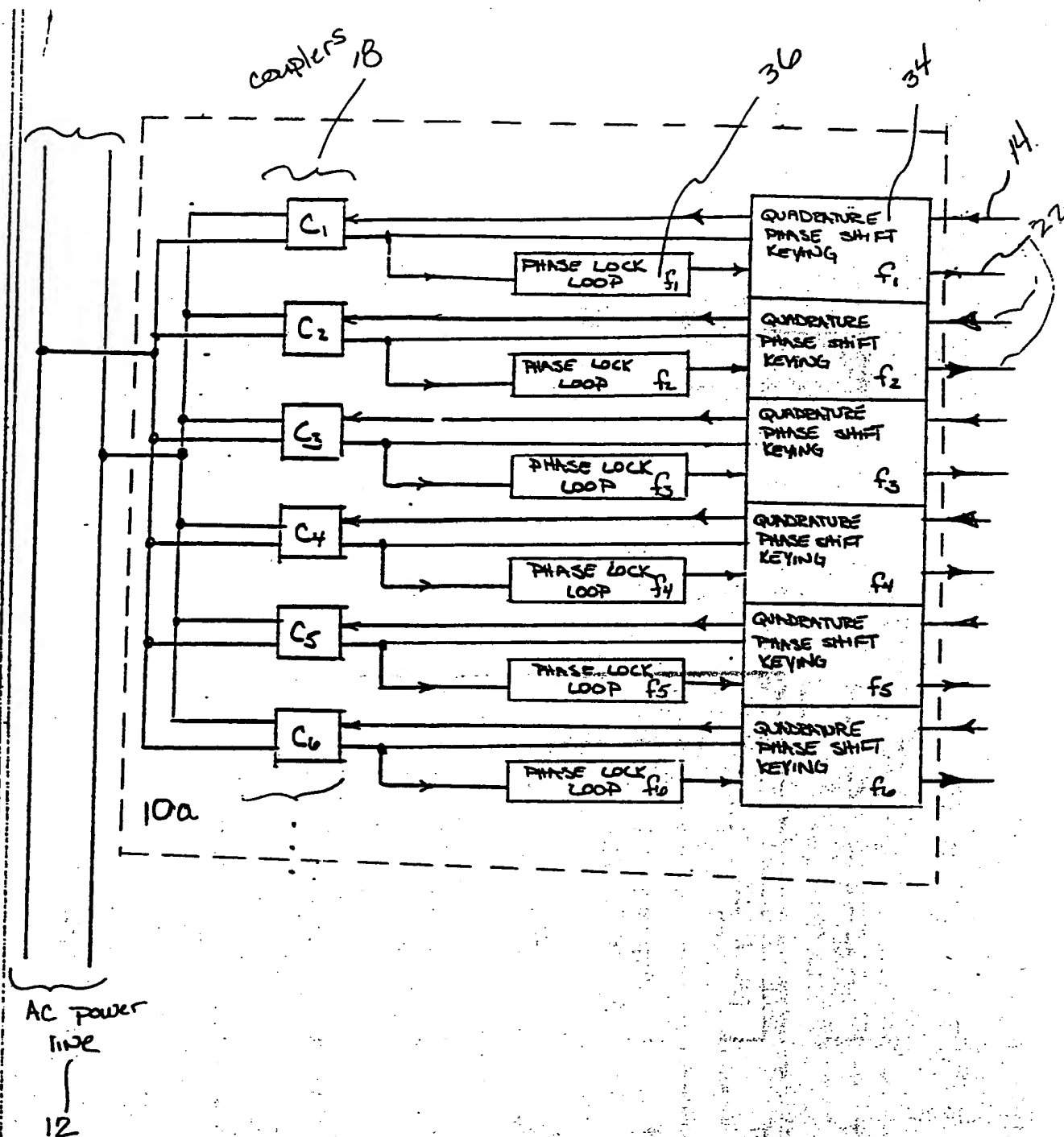connecting second data stream to the second electronic
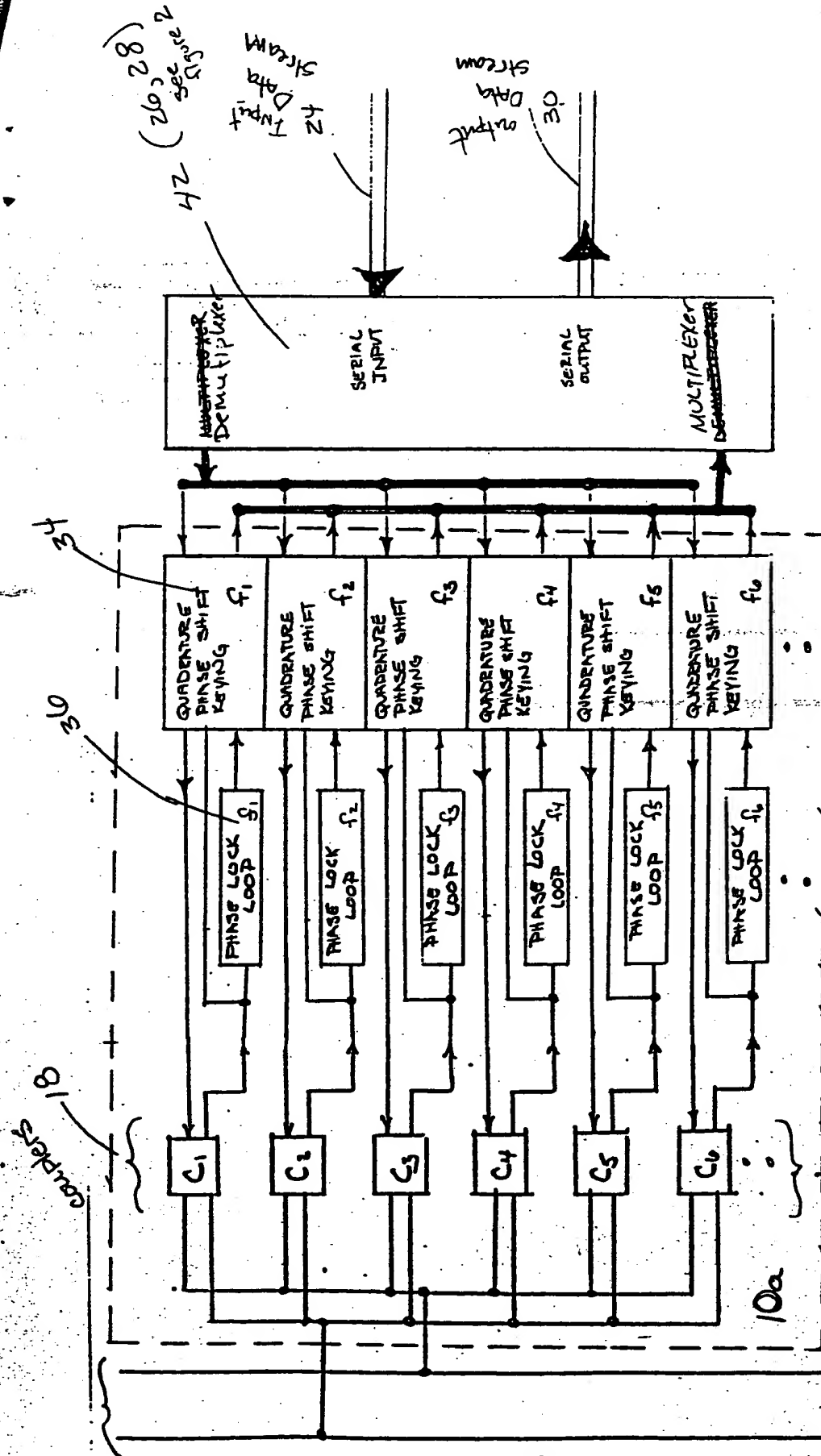
processor.

FIG 1
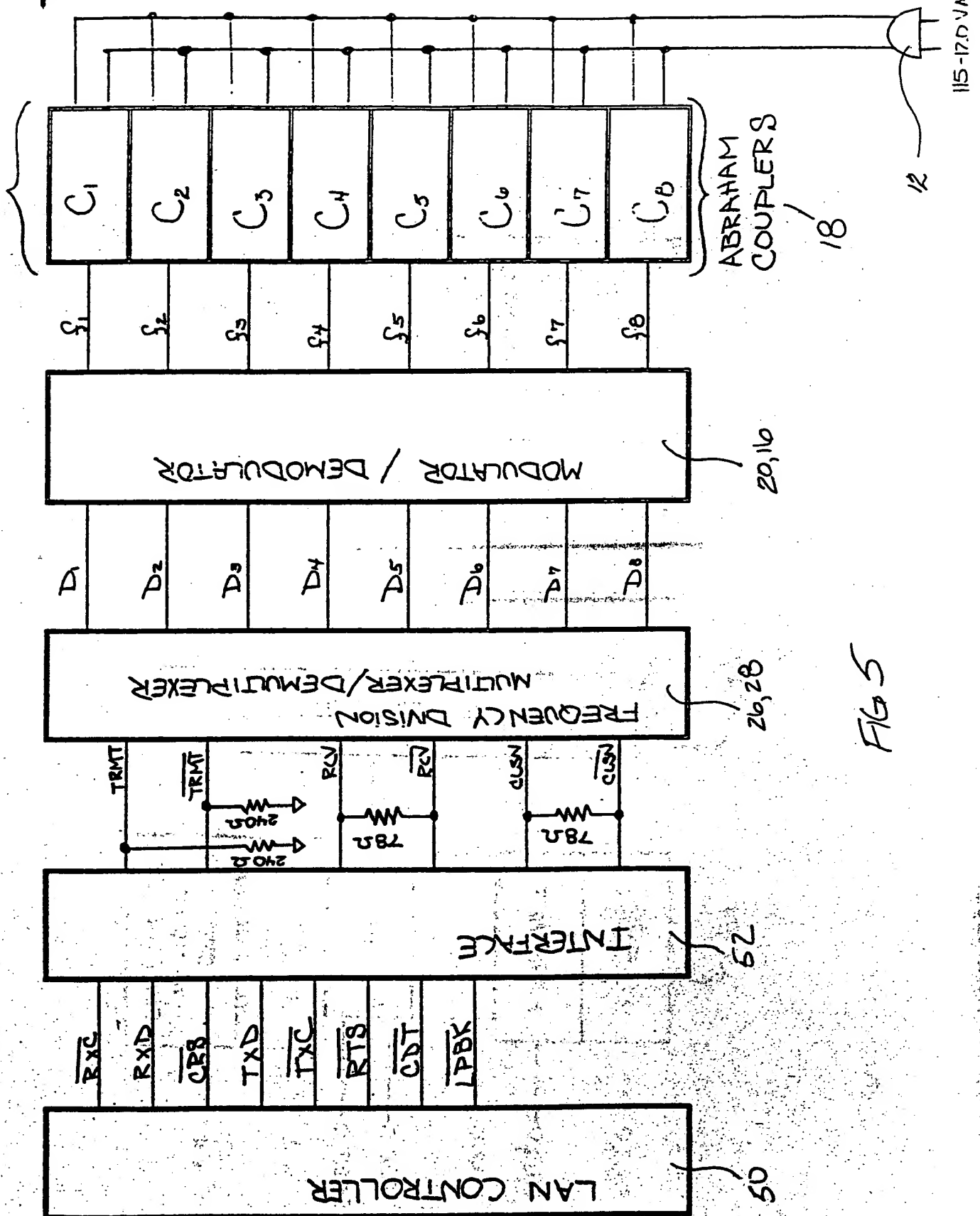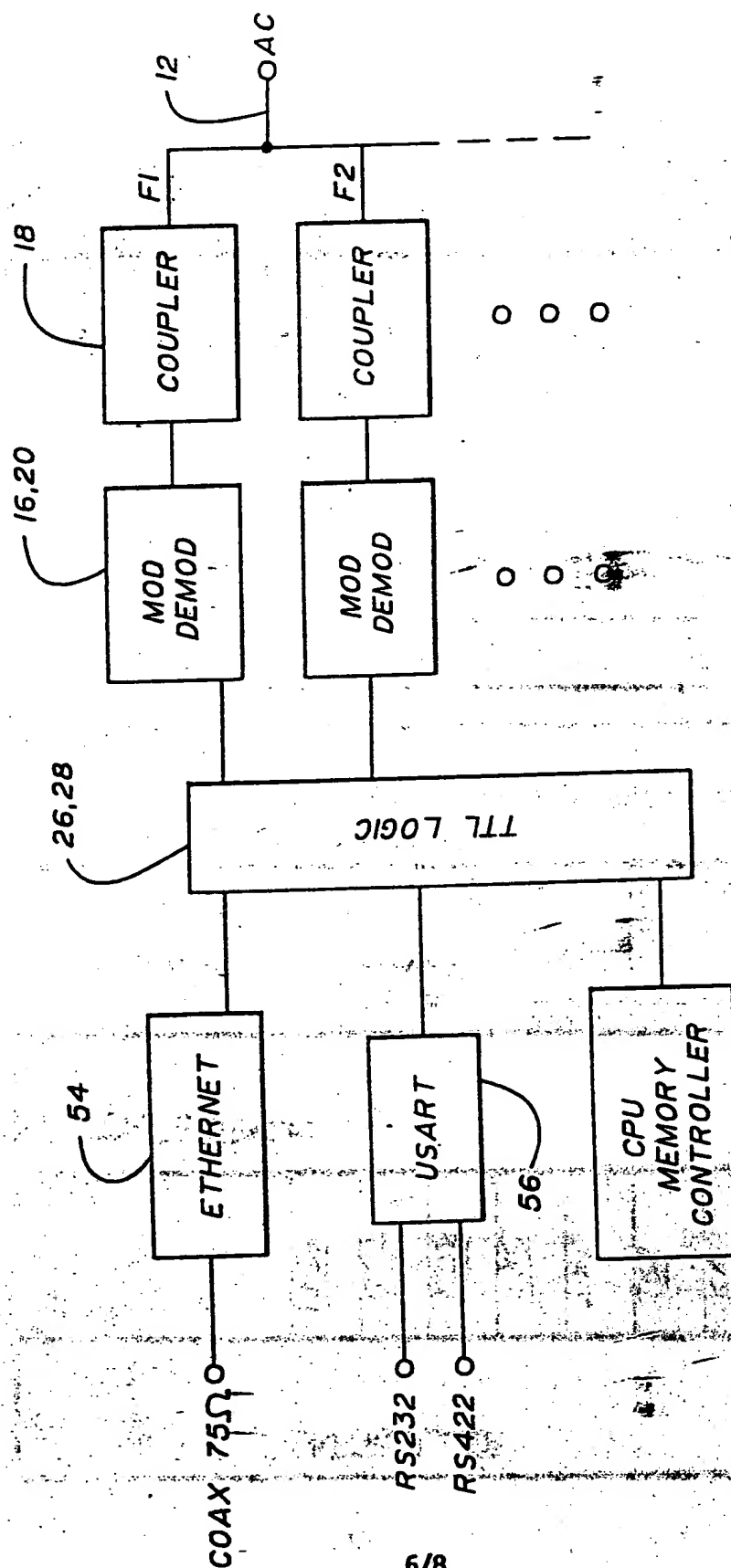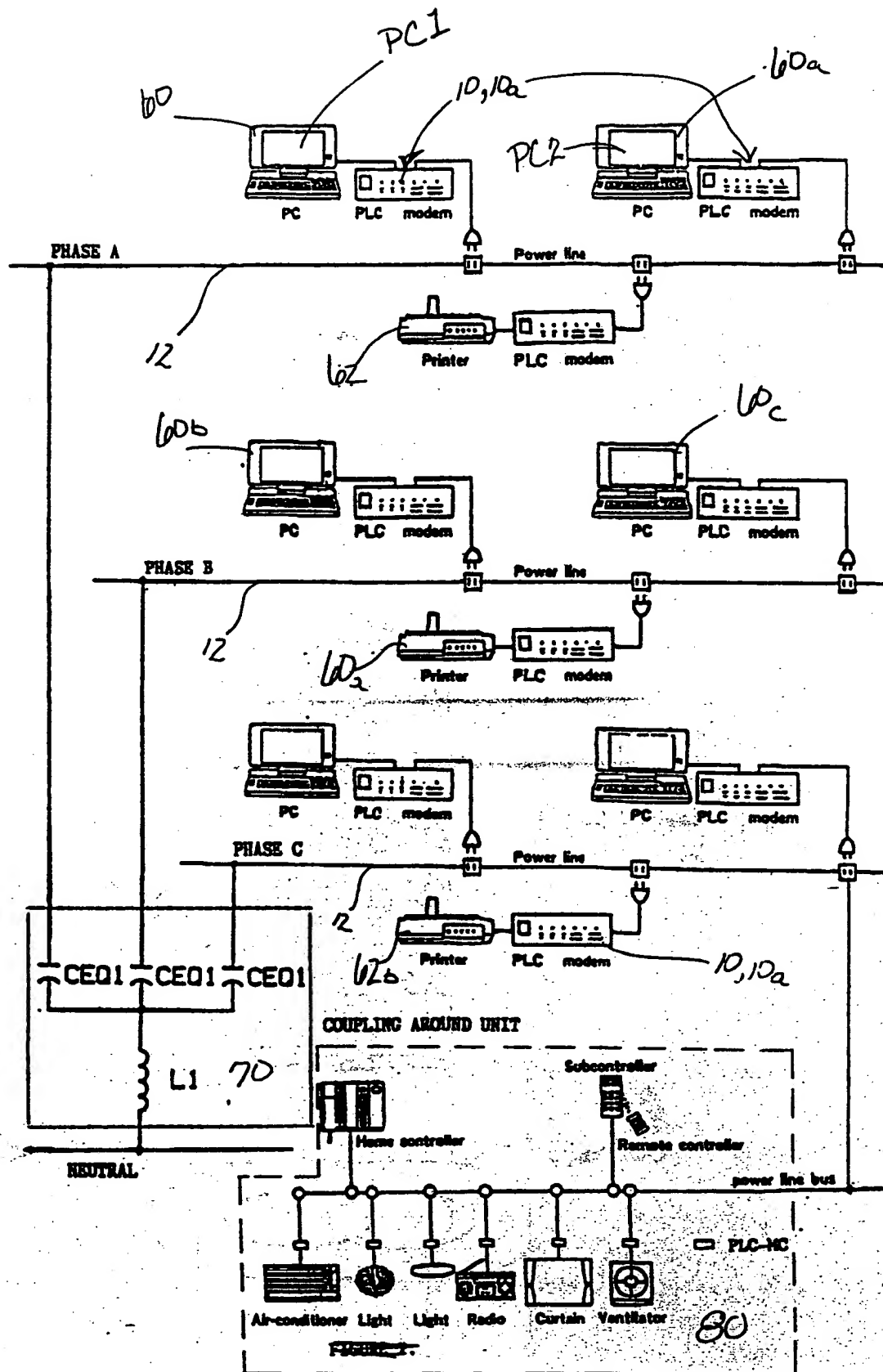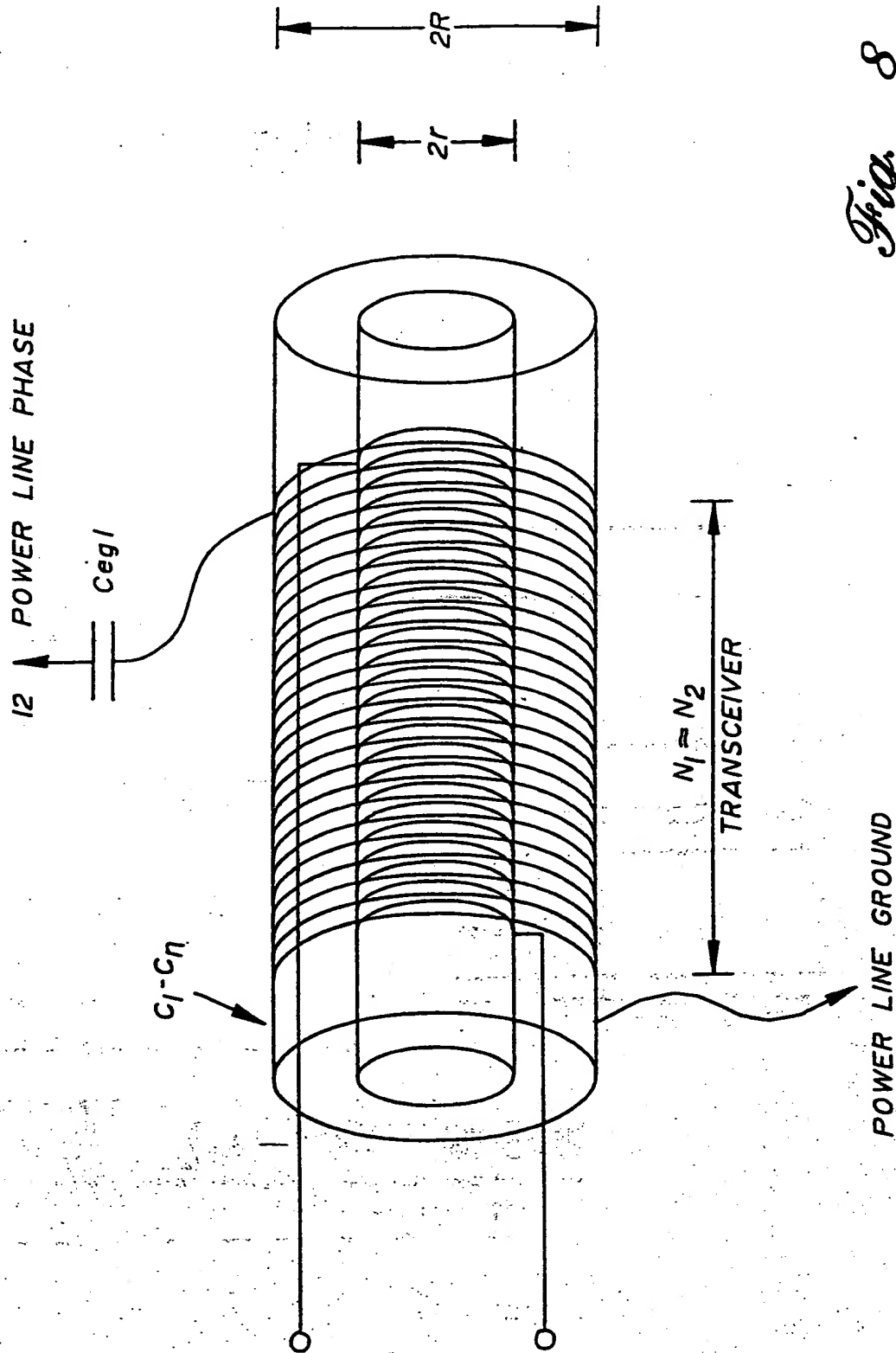
1/8

FIG 2

FIG 3

FIG 4

FIG 5

Fig. 6

FIGURE 7

Fig. 8

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :H04B 1/38; H04L 5/16, 27/10; H04M 11/04

US CL :375/8,54,53; 340/310A,310R

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 375/8,54,53; 340/310A,310R; 340/825.58; 375/7,9,52,83,85,37; 455/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

Please See Extra Sheet.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A, P	US, A, 5,185,591, (SHUEY) 09 February 1993 see Figure 2 and col. 2 line 45 to col. 2, line 65.	1,11,21
A	US, A, 4,815,106, (PROPP ET AL) 21 March 1989 see col. 5 lines 34-38.	1,11,21
A	US, A, 4,355,303, (PHILLIPS ET AL) 19 October 1982 see col. 1 lines 38-46.	1,11,21
A	IEEE Communications Magazine, May 1990, J.Bingham, "Multicarrier Modulation for Data Transmission: An Idea whose Time Has Come," pages 5-14, see page 5 and Figure 1.	1,11,21

☐ Further documents are listed in the continuation of Box C.   ☐ See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be part of particular relevance	
"E" earlier document published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 August 1993	27 AUG 1993

Name and mailing address of the ISA/US	Authorized officer
Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	CURTIS KUNTZ Duane Kobayashi SUPERVISORY PATENT EXAMINER GROUP 2600
Facsimile No. NOT APPLICABLE	Telephone No. (703) 305-4859

B. FIELDS SEARCHED

Electronic data bases consulted (Name of data base and where practicable terms used):

APS Search: Modem and power line and (phase shift or PSK) Modem (20W) power line.

IEEE/IEE CD system: Power line and (Modem or phase shift).